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Nielsen, Jacob; Ellegaard, Peter

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Jacob Nielsen, Peter Ellegaard

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Jacob Nielsen, Peter Ellegaard
i6jn@civil.auc.dk, i6pe@civil.auc.dk
Department of Building Technology and Structural Engineering,
Aalborg University, Sohngaardsholmsvej 57, DK-9000 Aalborg, Denmark

Abstract

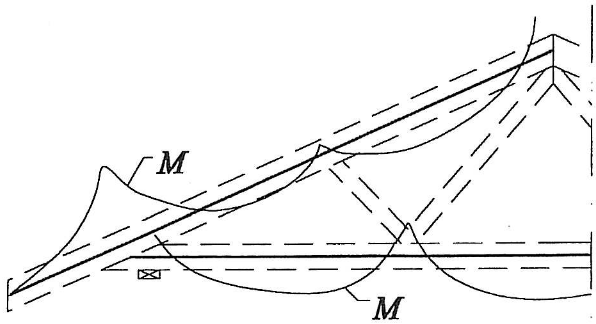
When designing timber trusses it is often found that the cross section controlling the dimensions of the top chord is located at a joint with a moment peak. However, the timber volume affected by the moment peak is rather limited and by embedding a punched metal plate in this area a reinforcement of the section is obtained, resulting in a more economic truss design.

In order to develop design methods for sections with plate reinforcement, bending tests have been made. The timber is Swedish spruce of strength class K-18(S8) and K-24(S10) with a thickness of 45 mm. The punched metal plate is from Gang-Nail Systems, type GNA 20 S with a thickness of 1 mm. The tests and the results are described.

1 Introduction

Truss designs in Scandinavia are often controlled by load combinations with snow. In these load combinations a typical variation of moment in the chords is shown in figure 1. The dimensions of the chords are controlled by the section forces (axial

Figure 1: Variation of the moment in the chords of a W-truss.

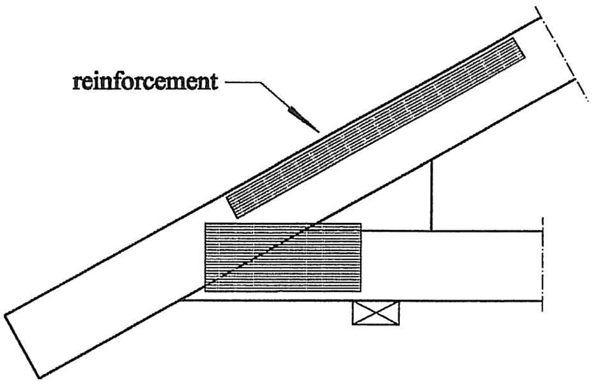


force and moment) in areas with a moment peak. In order to obtain optimal truss designs these sections attract special attention.

The fact that the moment capacity of timber loaded with a moment peak is larger than the moment capacity calculated with the bending strength determined according to EN 408, has led to a stress increase factor for the bending strength, see Riberholt et al. (1979). However, even with the stress increase factor the dimensions of the chords may still be controlled by the sections with moment peaks.

The above fact has provided breeding ground for the idea to reinforce the dimension controlling areas with a nail plate of same type used in the connections of the truss, see figure 2. The expenses of the reinforcement will be low as the expenses of nail plates are low compared to the expenses of timber and the embedding of the reinforcing plates can easily be added to the existing manufacturing process of the trusses.

Figure 2: Heel joint with a wedge and a reinforcement.



The reinforcing effect of the nail plates in areas with a moment peak is analysed by tests. The tests and the test results are described in this paper.

2 Test series

The test programme consists of 12 different test series. 11 series with 10 samples and 1 series with 20 samples. There are series with different strength classes, plate sizes and timber heights, see figure 3 and table 1. For reference there are made series without plate reinforcement. The used timber is Swedish spruce with 45 mm thickness. The timber were selected and graded by a truss plant.
GNA 20 S plates from Gang-Nail Systems are used for reinforcement. The thickness of the nail plate is 1 mm and the length of the nails is about 8 mm. All plates are located at the centre of the beams 10 mm from the tension edge.

The test specimens have been conditioned and manufactured according to prEN 1075. The moisture content of the timber was about 10-12%.

To obtain a section with a moment peak all samples are loaded in 3-point bending, see figure 4. According to EN 408 the load is applied at constant loading head movement (deformation controlled) so that the maximum load is reached within 300s(±120s). The loading heads have a width of 100 mm.

The vertical displacements are measured with three HBM displacement transducers of type W50TK(± 50mm), see figure 4.

A storage program from HBM, (UG6IEBE, 15/9-89), is used to store the data from the forces and the displacement measurings through an HBM data acquisition system (HBM UGR 60). The recording frequency is 1 Hz. The data are saved on disk.

Table 1: Test program with 12 different series.

Series no.	No. of tests	Timber grade	Timber h mm	Timber span mm	Plate width w mm	Plate length l mm
RS1	10	K-18	120	1500	-	-
RS3	20	"	170	2100	-	-
RS5	10	K-24	170	"	-	-
RS6	10	K-18	120	1500	34	776
RS7	10	"	120	"	76	516
RS8	10	"	120	"	34	516
RS9	10	"	170	2100	76	516
RS10	10	"	170	"	34	776
RS11	10	"	170	"	34	258
RS12	10	"	170	"	34	516
RS14	10	K-24	170	"	34	776
RS15	10	"	170	"	34	516

Figure 3: Test series with plate reinforcement. Dimensions in mm.

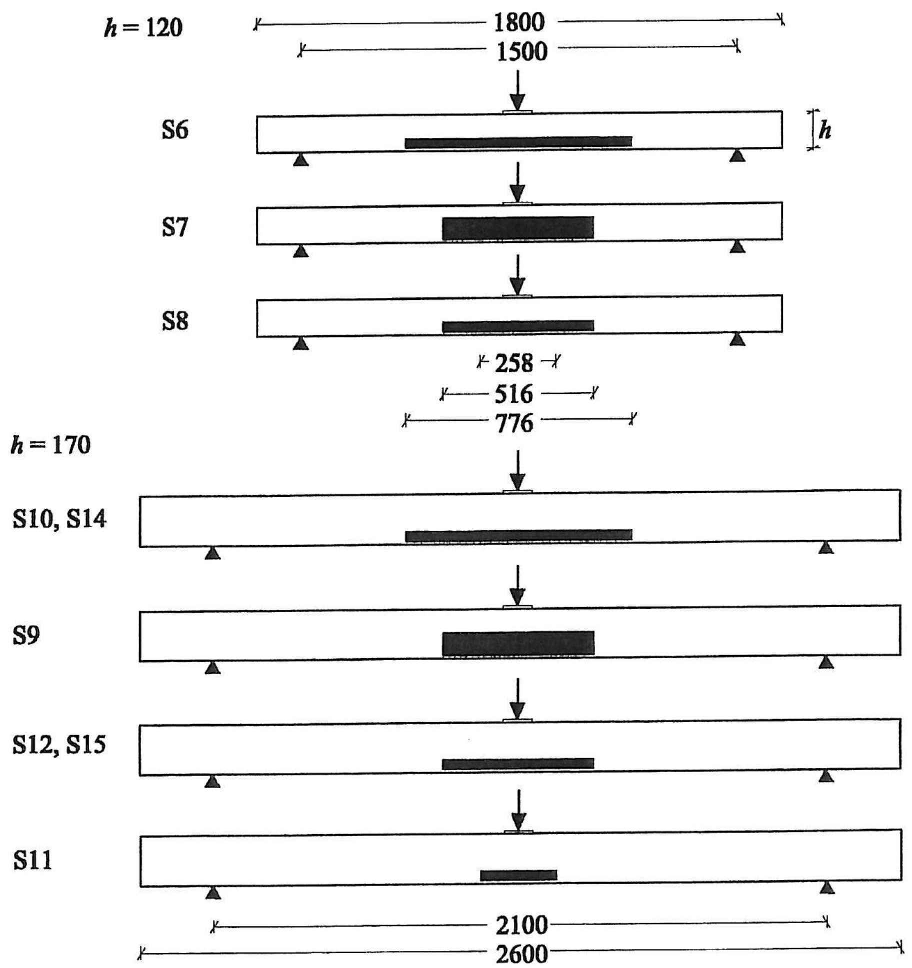
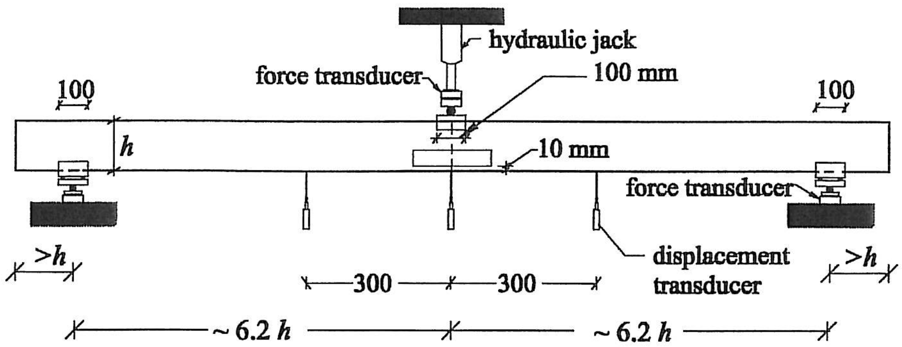


Figure 4: Test arrangement for beams in 3-point bending.



3 Result and Discussion

It was observed that some of the specimens in the series planned with timber in strength class K-18 had a look very common to the timber in strength class K-24. In many specimens the 100 mm loading head was more or less embedded into the beam. In a few cases the indentation in the wood from the loading head was more than 10 mm.

The mean value m, the standard deviation s, and the coefficient of variation δ are calculated according to EN 1058. ρ is the density of the wood.

3.1 Strength

In table 2 the results for the failure load in series with timber height $h = 120$ mm are given.

Table 2: Failure load in series with $h = 120$ mm.

Test	Timber		Plate		Failure load		
no.	grade	$m(\rho)$ kg/m^3	w mm	l mm	m kN	s kN	δ %
RS1	K-18	448	-	-	12.41	2.94	24
RS6	K-18	461	34	776	16.42	3.04	19
RS7	K-18	461	76	516	15.32	2.46	16
RS8	K-18	465	34	516	15.02	2.80	19

In table 2 it is seen that the failure loads for the series with a reinforcement are increased between 20 to 30% compared to the series without plate. The reinforcing effect is optimal with long reinforcement plates.

In the series with 776 mm reinforcement (RS6) most of the failure occurred within the area of the reinforcement. In series RS7 and RS8 almost half of the failures occurred outside the reinforcement area. Failure within the reinforcing area causes no tension failure in the plate. The decreased coefficient of variation in tests with a reinforcement shows that the failure load is less sensitive to weak sections at the moment peak. The reinforcement changes the properties of the failure from a brittle failure to be more ductile as the plastic (horizontal) part of the load displacement curves is more distinct.

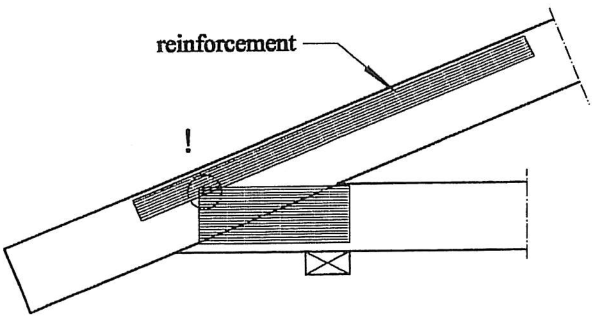
In table 3 the results for the failure load in series with timber height $h = 170$ mm are given.

Table 3: Failure load in series with $h = 170$ mm.

Test	Timber		Plate		Failure load		
no.	Grade	$m(\rho)$	w	l	m	s	δ
		kg/m^3	mm	mm	kN	kN	%
RS3	K-18	482	-	-	21.15	3.68	17
RS5	K-24	472	-	-	20.17	4.32	21
RS9	K-18	458	76	516	19.94	3.67	18
RS10	K-18	457	34	776	20.23	2.97	15
RS11	K-18	473	34	258	22.01	3.98	18
RS12	K-18	507	34	516	21.80	5.62	26
RS14	K-24	474	34	776	22.78	1.69	7
RS15	K-24	487	34	516	22.66	3.44	12

In table 3 it is seen that the effect of the reinforcement on the failure load is vanishing. In series with long plates (RS10), where the effect is assumed to be most distinct, the mean value of the failure load is even less than the mean value of the beams without a reinforcement. The coefficient of variation in the series is almost the same. Failure within the reinforcing area causes failure in the plate also, in a form as tension failure in the steel or in few cases as withdrawal of the teeth. An examination of the failure types in the tests with a low failure load compared to the mean value of each series shows that the failure in many cases occurred at knots within the reinforcing area. As it was expected that the reinforcement would have an effect in exactly these cases indicates that the tension strength of the plate is to low for a section height of 170 mm. A plate with an increased tension capacity compared to the GNA 20 S may have a larger effect on the moment capacity of the beam. If the reinforced beams shall be an option for practical truss manufacturing it demands the reinforcement to be made by rather small strips (w < 40-50 mm) of plate as the area of a large reinforcing plate may conflicts with a beam connecting plate, see figure 5.

Figure 5: A reinforcement plate in conflict with a beam connecting plate.



The failure for all beams with or without reinforcement is very sensitive to the appearance and the size of the knots in the tension side in the area of the load supply.

There was not found any reason for the high coefficient of variation in series RS12.

As mentioned above some of the beams in series planned with K-18 had a look to be graded in K-24. This assumption is supported by the results from series RS3 and RS5. The mean value and the coefficient of variation of the series with K-18

(RS3) are found to be lower than the same values in series with K-24 (RS5).

In some tests in RS10, RS12, RS13 and RS15 the failure was caused by shear failure in the wood. The crack is stated just below the plate and ran out to the end of the beam. The size of the failure load for this failure type is found to be between 20.5 and 30 kN.

3.2 Stiffness

In tables 4 and 5 the mean value of the stiffness from series with timber heights of 120 mm and 170 mm is given, respectively. The stiffness is found as the slope of the straight line portion of the load displacement curve for the mid section.

Table 4: Mean value of stiffness in series with $h = 120$ mm.

Test	Timber		Plate		Stiffness		
no.	Grade	$m(\rho)$ kg/m^3	w mm	l mm	m N/mm	s N/mm	δ %
RS1	K-18	448	-	-	759	128	17
RS6	K-18	461	34	776	1000	142	14
RS7	K-18	461	76	516	1034	168	16
RS8	K-18	465	34	516	934	151	16

Table 5: Mean value of stiffness in series with $h = 170$ mm.

Test	Timber		Plate		Stiffness		
no.	Grade	$m(\rho)$ kg/m^3	w mm	l mm	m N/mm	s N/mm	δ %
RS3	K-18	482	-	-	971	140	15
RS5	K-24	472	-	-	1064	110	10
RS9	K-18	458	76	516	970	135	14
RS10	K-18	457	34	776	989	113	11
RS11	K-18	473	34	258	1061	195	18
RS12	K-18	507	34	516	1115	241	22
RS14	K-24	474	34	774	1100	107	10
RS15	K-24	487	34	516	1149	142	12

The effect of the reinforcement on the stiffness is almost the same as for the strength. In series with $h = 120$ mm the stiffness is increased with 20% to 30%, however, in series with $h = 170$ mm the increasing effect is vanishing.

4 Conclusion

Based on the tests the following conclusions can be made:

- The failure load and the stiffness of 120 mm beams with reinforcement are increased with 20 to 30%. The failure becomes more ductile with a reinforcement.
- The effect of a reinforcement on 170 mm beams is very limited.

In further analysis it is recommended to:

- use a plate with high tension capacity (thickness > 1 mm) in beams with a section height of 170mm.
- locate the reinforcement closer to the tension edge of the timber (< 10 mm).

- limit the width of the reinforcing (< 40 - 50 mm)
- test beams with other section heights and load conditions.

The results from the test programme will be used to develop and calibrate an advanced truss model. The truss model is described in Nielsen (1996) and Ellegaard et al. (1999).

5 References

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Dept. of Building Technology and Structural Engineering
Aalborg University, December 1999
Sohngaardsholmsvej 57, DK-9000 Aalborg, Denmark
Phone: +45 9635 8080 Fax: +45 9814 8243
http://www.civil.auc.dk/i6